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TI Lead-free tin alloy solders for electric circuits

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AB The Sn alloy solders contain (1) Ag 0.1-20, Bi 0.1-25 and/or In 0.1-20, and optionally Cu 0.1-3.0 and/or Zn 0.1-15%, or (2) Sb 0.1-20, Bi 0.1-30 and/or In 0.1-20, and optionally Cu 0.1-3.0 and/or Zn 0.1-15%. The solders have low m.p., high strength and wettability, and are suitable for soldering electronic parts.

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Applicant: Matsushita Electric Industrial Co., Ltd.

[Title of the Invention] Solder Material

[Abstract]

[Object] To provide a lead-free solder material having a sufficiently low melting point for enabling the assembling of electronic parts, and also high levels of mechanical strength and wetting property.

[Features] An alloy consisting basically of Sn and Ag, having a silver content of 0.1 to 20% by weight, and further containing 0.1 to 25% by weight of Bi or 0.1 to 20% by weight of In, or both, the balance being Sn.

[What Is Claimed Is]

[Claim 1] A solder material comprising an alloy consisting basically of Sn and Ag, having a silver content of 0.1 to 20% by weight, and further containing 0.1 to 25% by weight of Bi or 0.1 to 20% by weight of In, or both, the balance being Sn.

[Claim 2] A solder material comprising an alloy consisting basically of Sn and Ag, having a silver content of 0.1 to 20% by weight, and further containing 0.1 to 25% by weight of Bi or 0.1 to 20% by weight of In, or both, the alloy further containing 0.1 to 3.0% by weight of Cu or 0.1 to 15% by weight of Zn, or both, the balance being Sn.

[Claim 3] A solder material comprising an alloy consisting basically of Sn and Sb, having an antimony content of 0.1 to 20% by weight, and further containing 0.1 to 30% by weight of Bi or 0.1 to 20% by weight of In, or both, the balance being Sn.

[Claim 4] A solder material comprising an alloy consisting basically of Sn and Sb, having an antimony content of 0.1 to 20% by weight, and further containing 0.1 to 30% by weight of Bi or 0.1 to 20% by weight of In, or both, the alloy further containing 0.1 to 3.0% by weight of Cu or 0.1 to 15% by weight of Zn, or both, the balance being Sn.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to a solder

material providing e.g. a solder cream used mainly for soldering parts on substrates for electronic circuits.

[0002]

[Prior Art] It has recently become more and more necessary to mount smaller electronic parts with a higher mounting density on substrates for electronic circuits. As a result, it has become necessary to use a more functional solder material.

[0003] The lead which the conventional solder materials (Sn-Pb alloys) contain have, however, been found to present an environmental problem. If articles made by using the conventional solder materials are thrown away, and exposed to acid rain, a large amount of lead, which is a harmful substance, is dissolved in the rain, and its toxicity presents a very serious problem. Therefore, it has become necessary to develop a solder material not containing lead (lead-less) which can replace the solder containing lead.

[0004] Reference is made to an example of the conventional solder materials. A typical solder alloy has been a eutectic alloy of tin and lead comprising 63Sn-37Pb (% by weight; also throughout the following description), and having a eutectic point of 183°C.

[0005] Reference is now made to examples of the solder alloys not containing lead. Sn-3.5Ag and Sn-5Sb alloy solders are superior to the Sn-Pb eutectic solder in mechanical strength. They are somewhat inferior to the Sn-Pb eutectic solder in

wetting property, but are still considered as good substitutes therefor.

[0006]

[Problems to Be Solved by the Invention] The Sn-3.5Ag and Sn-5Sb alloy solders, however, have so high melting points as to require a working temperature of 220°C to 250°C which is too high for any damage-free work for assembling electronic parts.

[0007] It is an object of this invention to provide a solder material having a lower melting point not presenting any problem as stated above, while also having high mechanical strength.

[0008]

[Means for Solving the Problems] According to a first aspect thereof, this invention is intended for overcoming the problem presented by the conventional Sn-3.5Ag alloy solder (having a melting point of 221°C), and is an alloy consisting basically of Sn and Ag, having a silver content of 0.1 to 20% by weight, and further containing 0.1 to 25% by weight of Bi or 0.1 to 20% by weight of In, or both, the balance being Sn.

[0009] According to a second aspect thereof, this invention is intended for attaining the same object, and is an alloy consisting basically of Sn and Ag, having a silver content of 0.1 to 20% by weight, and further containing 0.1 to 25% by weight of Bi or 0.1 to 20% by weight of In, or both, the alloy further containing 0.1 to 3.0% by weight of Cu or 0.1 to 15% by weight of Zn, or both, the balance being Sn.

[0010] According to the first and second aspects of this invention, the alloy preferably has a silver content of around 3.5% by weight and in the range of 0.5 to 6% by weight. As regards its main constituent, it preferably has a tin content of 75 to 98% by weight.

[0011] According to a third aspect thereof, this invention is intended for overcoming the problem presented by the conventional Sn-5Sb alloy solder (having a melting point of 240°C), and is an alloy consisting basically of Sn and Sb, having an antimony content of 0.1 to 20% by weight, and further containing 0.1 to 30% by weight of Bi or 0.1 to 20% by weight of In, or both, the balance being Sn.

[0012] According to a fourth aspect thereof, this invention is intended for attaining the same object, and is an alloy consisting basically of Sn and Sb, having an antimony content of 0.1 to 20% by weight, and further containing 0.1 to 30% by weight of Bi or 0.1 to 20% by weight of In, or both, the alloy further containing 0.1 to 3.0% by weight of Cu or 0.1 to 15% by weight of Zn, or both, the balance being Sn.

[0013] According to the third and fourth aspects of this invention, the alloy preferably has an antimony content of around 5% by weight and in the range of 1 to 9% by weight. As regards its main constituent, it preferably has a tin content of 80 to 98% by weight.

[0014]

[Effects] Bi or In, or both are added to the alloy according to the first or second aspect of this invention and consisting basically of Sn and Ag for the purpose of lowering its melting point. This purpose is attained when the proportion of Bi or In is at least 0.1% by weight.

[0015] No proportion of Bi or In exceeding 25 or 20% by weight is desirable, since no desirable mechanical strength can be obtained. The increase of Bi or In makes it possible to obtain a material having better wetting property.

[0016] Figure 1 shows the melting points of Sn-3.5Ag alloys further containing Bi in relation to the proportion of Bi which they contain. As is obvious from Figure 1, the melting point drops in a linear pattern with an increase in the proportion of Bi, and the alloy containing 25% by weight of Bi has a melting point of 175°C.

[0017] Figure 2 shows the tensile strengths of Sn-3.5Ag alloys further containing Bi in relation to the proportion of Bi which they contain. As is obvious from Figure 2, the alloy containing about 10% by weight of Bi has the highest tensile strength, and the alloy containing more than 25% by weight of Bi has a tensile strength lower than that of the alloy not containing Bi.

[0018] Figure 3 shows the wetting properties of Sn-3.5Ag alloys containing 3% by weight of Bi (Sn-3.5Ag-3Bi) and ones containing 20% by weight of Bi (Sn-3.5Ag-20Bi). As is obvious from Figure 3, they are comparable in wetting property to 60Sn-40Pb eutectic

solder, and the alloys containing 20% by weight of Bi have a better wetting property than the 60Sn-40Pb eutectic solder.

[0019] The tendencies shown in Figures 1 to 3 are observed also with Sn-3.5Ag alloys containing In, alloys containing both Bi and In, and alloys containing different proportions of Ag.

[0020] The addition of In is also effective for restraining the formation of Sn whiskers.

[0021] According to the second aspect of this invention, Cu or Zn, or both are added to the alloy consisting basically of Sn and Ag and further containing Bi or In, or both, for improving its strength.

[0022] The proportion of Cu or Zn is at least 0.1% by weight to ensure the strength of the alloy. It does not exceed 3.0 or 15% by weight, so that the alloy may have a melting point below 221°C.

[0023] Bi or In, or both are added to the alloy according to the third or fourth aspect of this invention and consisting basically of Sn and Sb for the purpose of lowering its melting point and improving its wetting property. This purpose is attained when the proportion of Bi or In is at least 0.1% by weight, and an undesirable lowering of its mechanical strength can be prevented if the proportion of Bi or In does not exceed 30 or 20% by weight.

[0024] According to the fourth aspect of this invention, Cu or Zn, or both are added to the alloy consisting basically of

Sn and Sb and further containing Bi or In, or both, for improving its strength.

[0025] The proportion of Cu or Zn is at least 0.1% by weight to ensure the strength of the alloy, and does not exceed 3.0 or 15% by weight, so that the alloy may have a melting point below 240°C.

[0026]

[Examples] Table 1 shows examples of solder materials embodying this invention and their compositions (% by weight).

[0027]

[Table 1]

		Composition (% by weight)								Melting point (°C)	Tensile strength (Kgf/mm^2)	Wetting property
		Sn	Ag	Sb	Bi	In	Zn	Cu	Pb			
Example	1	Balance	3.5		3					214	7.43	A
	2	Balance	3.5		20					187	9.02	B
	3	Balance	3.5			3				214	6.00	G
	4	Balance	3.5			10				200	5.90	G
	5	Balance	6		10	7				198	9.03	G
	6	Balance	3.5		3		1	0.7		210	11.8	G
	7	Balance	3		3			0.5		211	8.40	G
	8	Balance		5	10					212	6.18	A
	9	Balance		5		10				214	5.36	A
Comparative Example	1	Balance	3.5							221	6.26	G
	2	Balance		5						240	6.27	A
	3	Balance							37	183	5.41	B

[0028] Examples 1 to 7 in Table 1 are of solder materials according to the first aspect of this invention as consisting basically of Sn (tin) and Ag (silver) and further containing Bi (bismuth) or In (indium), or both.

[0029] Examples 6 and 7 are of solder materials according to the second aspect of this invention as consisting basically of Sn and Ag and further containing at least one of Bi and In, and at least one of Cu (copper) and Zn (zinc).

[0030] Examples 8 and 9 are of solder materials according to the third aspect of this invention as consisting basically of Sn and Sb (antimony) and further containing at least one of Bi and In.

[0031] Table 1 also shows conventional solder materials as Comparative Examples with their compositions (% by weight).

Comparative Example 1 is an Sn-3.5Ag alloy solder, Comparative Example 2 is an Sn-5Sb alloy solder, and Comparative Example 3 is a 63Sn-37Pb eutectic solder.

[0032] Table 1 shows the melting point, tensile strength and wetting property of each of the materials according to Examples 1 to 9 and Comparative Examples 1 to 3. The results of their evaluation as to wetting property are shown as B:Best, G:Good, and A:Average. All of the materials shown in Table 1 were Average, or better, and none was bad.

[0033] As is obvious from Table 1, the addition of Bi or In made it possible to lower the melting point of the Sn-Ag or Sn-Sb alloy solder, and the materials according to Examples 2, 4 and 5 had a melting point as low as 200°C or below. The materials according to this invention were comparable or superior in mechanical strength to the 63Sn-37Pb eutectic solder. They were acceptable for practical use in wetting property, too, and the material according to Example 2 was as good as the 63Sn-37Pb eutectic solder in wetting property.

[0034] A solder cream was prepared by forming a paste from the solder material according to Example 6 (containing 3.5% Ag, 3% Bi, 1% Zn and 0.7% Cu, all on a weight basis, the balance being Sn), or Example 2 (containing 3.5% Ag and 20% Bi on a weight basis, the balance being Sn), and was used for chip packaging tests. The results are shown in Table 2 in comparison with the results of tests conducted by using a solder cream prepared from

the material according to Comparative Example 3 (63Sn-37Pb eutectic solder).

[0035] The paste was formed by using a flux consisting of 40% by weight of a solvent, 55.31% by weight of rosin, 0.69% by weight of an activator and 4% by weight of a thixotropic agent.

[0036]

[Table 2]

	Number of chips mounted 1005	Number of tomb stone chips	Percentage thereof (%)
Example 6	10,000	170	1.7
Example 2	10,000	155	1.55
Comparative Example 3	10,000	150	1.5

[0037] As is obvious from Table 2, the products of this invention can be used for chip mounting substantially as effectively as the conventional material, since the percentages of chips lifted off when the materials of Examples 6 and 2 were used were 1.7% and 1.55%, respectively, and were substantially equal to 1.5% as observed when the material of Comparative Example 3 was used.

[0038] Although no specific example has been given of the material according to the fourth aspect of this invention, it is obvious that a material embodying the fourth aspect of this invention is easy to obtain by adding Zn or Cu to, for example, the material of Example 8 (according to the third aspect of this invention), as it is easy to obtain Example 6 (according to the second aspect of this invention) from Example 1 (according to

the first aspect thereof).

[0039]

[Advantages of the Invention] This invention provides a lead-free solder material having a sufficiently low melting point for enabling the assembling of electronic parts, and also high levels of mechanical strength and wetting property.

[Brief Description of the Drawings]

Figure 1 is a graph showing the relation as found between the proportions of Bi added to Sn-3.5Ag alloys and the melting points thereof;

Figure 2 is a graph showing the relation as found between the proportions of Bi added to Sn-3.5Ag alloys and the tensile strengths thereof; and

Figure 3 is a graph comparing materials embodying this invention and comparative materials in wetting property.